

Workshop on Solar Electric Propulsion

Dean Marvin
Aerospace Corporation
El Segundo, California

David Bents
NASA Lewis Research Center
Cleveland Ohio

This workshop was well-attended, with over thirty participants. The meeting room was filled to capacity. Latecomers were forced to go across the hall and fetch extra chairs.

As the meeting opened, Dr. Marvin introduced himself and his co-chairperson (D.J. Bents) and presented some opening questions that Drs. Flood and Bailey had collected to challenge the group. Mr. Bents then asked the participants how many of them considered themselves to be photovoltaic technologists, and how many considered themselves to be SEP advocates. The technologists would be persons basically interested in learning more about SEP and application of their technology to electric propulsion. Advocates would be those who not only were already familiar with SEP, but also of the strong opinion that it is a useful concept, with merit in being considered for upcoming missions. To the definition of Technologist, approximately twenty people raised their hands. To the definition of Advocate, 6 people raised their hands.

Dr. Marvin then delivered a few advocacy viewgraphs about the advantages of SEP over chemical propulsion for orbit-raising. This presentation culminated in a lengthy discussion of the ELITE SEP flight experiment, an electric propulsion technology demonstration program executed by the Air Force Phillips Lab in Albuquerque. During the discussion, which was sparked with spirited interactions from several members of the group, the technical objectives of this program and details of the anticipated flight experiments were presented to the participants as an example of the issues pertinent to SEP solar array development.

The purpose of ELITE is to demonstrate operation of solar array powered electric thrusters for raising spacecraft from parking orbit to higher altitudes, leading to definition of an operational SEP OTV for Air Force missions. According to Dr. Marvin, many of the problems or potential problems that may be associated with SEP are not well understood nor clearly identified, and system level phenomena such as interaction of thruster plume with the solar arrays cannot be simulated in a ground test. Therefore, an end-to-end system flight test is required to demonstrate solar electric propulsion.

The ELITE project is being carried out on a cost-share basis with TRW, who will provide the spacecraft bus. The Air Force will provide a Titan II launch vehicle and is procuring the electric thruster system (ammonia arcjet is baselined) and a solar array, through an RFP due to be released in November. An array of approximately 10 kWe is required, with scaleability to larger sizes as would be used on an operational SEP OTV. The anticipated launch date is the end of FY1996. ELITE will be launched into a LEO parking orbit, then spiral to a final altitude of 2150 nmi. Various on-orbit maneuvers, including repositioning and orbital plane changes, will be demonstrated during the test. The maneuvers are an important application of EP to military space missions, according to Air Force Space Command. When final orbit is reached, the thrusters will be turned off and the vehicle will remain there until it fails due to Van Allen radiation. There is also the option of a thruster restart demonstration following a radiation exposure period equivalent to LEO to GEO transfer. Since the ELITE spacecraft would have a large amount of electrical power available at end of its mission to service experimental packages, the program office is actively seeking outside experiments for spacecraft payloads.

As Dr. Marvin finished his presentation, some discussion arose concerning the solar array for ELITE. Due to the spacecraft's destination, an opportunity for definitive degradation tests of the various competing space cell types has been presented. Should ELITE be considered mainly a demonstration of electric propulsion or could it also be considered an experiment for solar arrays in a severe radiation environment? Dr. Marvin responded that spacecraft bus requirements, integration and packaging concerns would most likely drive array selection to a single array technology despite the desirability of creating a solar cell testbed that demonstrates several technologies.

Discussion then turned to cell and array design. Which approach is more favorable for operation in a high natural radiation environment -- concentrator PV arrays with their inherent capability for shielding and temperature control, or thin planar arrays using the newer, more radiation-resistant materials? One of the participants then asked whether single concentrator arrays should be considered. Others replied that the single versus multi-concentrator PV array issue had been considered years ago in previous (mainly terrestrial) array development programs. Multiconcentrator designs had proven to be superior in all cases considered. An example was cited from a DoE/Sandia program in the early 80's where the experience with large single concentrators had been singularly disappointing.

A question was then raised about the Topaz flight experiment sponsored by SDIO. Mention of Topaz sparked a lively discussion, since this proposed flight demonstration would use a Russian space reactor to power an electric thruster equipped spacecraft from a medium low (nuclear safe) orbit to higher altitudes. Since this project also anticipates a 1996 launch date, it appears to compete with the ELITE program. Does demonstration of nuclear electric propulsion (such as Topaz flight experiment) support, or undermine a solar electric propulsion demonstration for the same mission?

Since the competitive potential of NEP versus SEP orbit raising could not be easily resolved in a photovoltaics conference, discussion turned back to the solar array. One stated objective of ELITE is scalability of the 10 kWe SEP flight experiment to a larger orbital tug that would be competitive with the chemical upper stages presently in use. However, packaging of larger array that is required for a SEP upper stage is a potential show-stopper. To be competitive with existing chemical propulsion upper stages, the deployed array would have to provide tens of kWe, but when stowed it would have to fit inside the shroud of a launch vehicle that is considerably smaller than the original one (that carried a chemical upper stage) it replaces. Several of the participants voiced the opinion that a 30 kWe array could not be made to fit inside the limited payload shroud of smaller launch vehicles such as a Delta.

Discussion's focus on ELITE finally ended when it was pointed out that there won't be much influence on the flight experiment since the array RFP for ELITE is already presently in final preparation and the workshop discussions, which may be of some benefit to potential competitors, comes too late to influence the RFP itself. It will be up to the government's proposal team to determine the level of technology and programmatic risk that is acceptable when these proposals are evaluated.

In the closing minutes of the workshop, one last question on the agenda was discussed. Are there any missions where EP offers such major benefits that the arguments in favor of EP over chemical thrusters are compelling? Most of the participants agreed that EP would look more attractive for higher delta V missions such as interplanetary flight than for orbit-raising. As an example, a recent study that considered sending a 200 kg scientific payload to the asteroid

Anteros was mentioned. If a chemical upper stage was used to fly this satellite, a Delta launch vehicle would be required. If an SEP upper stage was available, however, the mission could be launched on a Taurus rocket instead. For this mission, the trip times were nearly identical for both upper stages. Unfortunately, nearly all of the marketplace for launch and boost stage propulsion appears to be in earth orbit raising. For earth orbit raising missions, the increased trip time associated with EP is not considered acceptable from an operational standpoint. The bottom line is that time, in terms of the infrastructure and support personnel required to navigate the satellite to its final destination, is money. Therefore the dilemma: how can the perceived operational disadvantage of SEP compared to a chemical upper stage (trip time of weeks rather than hours from parking to operation orbit) be ameliorated or reduced? The discussion highlighted the reluctance of mission users to try new technology unless there is a major tangible benefit.